

**PLASTIC EXPULSION PROCESS FOR
FORMING HOLLOW TUBULAR PRODUCTS**

Cross Reference to Related Applications

[0001] This application is a continuation-in-part of United States Patent Application Serial No. 09/902,354, filed on July 10, 2001, and entitled "Plastic Expulsion Process."

Technical Field

[0002] The present invention relates to the field of injection molding of plastic materials, and in particular to gas assisted molding.

Background of the Invention

[0003] Injection molding of plastic materials is well known and widely practiced as a means of manufacturing an ever-increasing diversity of plastic components for industrial and consumer use. During the last two decades, versions of the process globally referred to as "gas assisted molding" have been developed and used to overcome some of the problems inherent in conventional molding, and to reduce costs and improve the quality of the final products.

[0004] In conventional gas molding, a gas, such as nitrogen, is injected into the molten plastic material after it has entered the mold. The low viscosity gas flows into the paths of least resistance within the more viscous plastic, thereby forming hollow channels within the plastic. The process is particularly beneficial for thick section moldings, such as handles, and weight savings of up to 45% or more can result. Also, the molding time cycles can be substantially reduced. In multi-section moldings, the injected gas tends to flow into the thicker sections, again forming hollow continuous channels through which pressure may be transmitted through the medium of the gas. This adds to the scope of the designer and removes some of the design restrictions of conventional molding.

[0005] One conventional gas assisted plastic molding process partially fills the mold cavity with an accurately controlled shot volume of plastic. Gas is then injected in order to continue the flow of plastic so that the cavity is filled with plastic and gas. The gas is used to exert outward pressure on the plastic material forcing it against the mold

cavity surfaces, thereby achieving a good replication of the mold surface on the plastic molded surface. After the plastic has solidified, the gas pressure is reduced, the gas is exhausted to atmosphere, and the mold is opened and the part ejected. This is sometimes referred to as a "short shot" process.

[0006] In another method, the mold cavity is completely or substantially filled with plastic material and then instead of injecting or packing more plastic into the cavity to compensate for the volumetric shrinkage of the plastic as it cools and solidifies, gas is injected into the plastic so that the gas expansion compensates for the plastic contraction. In practice, the initial gas penetration will continue to expand during the cooling cycle while the plastic is shrinking in volume. This is sometimes referred to as a "full shot" process.

[0007] In the "full shot" process, it is sometimes difficult to achieve sufficient gas penetration along intended gas channels because there is insufficient volumetric shrinkage of the plastic to provide space for the gas. In such cases, a method of enabling some plastic to outflow from the mold cavity into overflow wells or "secondary" cavities is helpful in providing space for the gas expansion.

[0008] In the "short shot" method, some moldings may also be difficult to fill with plastic and gas to the extremities of the molded article cavity. If the shot volume is too little, the gas may break through the leading edge of the plastic material during filling, thereby losing control of the gas. If the shot volume is too high, the gas will not reach the extremities of the cavity. Therefore thick section moldings using the "short shot" process can also benefit from an additional displacement of plastic from the article cavity into an overflow cavity.

[0009] A method of at least partially filling the cavity before injection of the gas is described in U.S. Patent No. 5,098,637. However, in order to use the method of this patent successfully, it is necessary to accurately control the shot volume for both "short shot" and "full shot" methods, because there is no resistance to prevent the plastic from flowing into and filling the overflow cavity before the gas is injected.

[0010] In the "short shot" process, the flow of plastic is temporarily stopped at the end of the filling sequence, and then typically there is a delay of up to five seconds before

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injection of the gas urges the plastic forward to complete the filling of the article cavity with plastic and gas and the overflow cavity with plastic. In the "full shot" process, the mold cavity is filled with, or substantially filled with, molten plastic and the gas is injected to compensate for the volumetric shrinkage of the plastic and to displace plastic into the overflow cavity. In both cases, it is not feasible to apply "packing pressure" by the molding machine because there is nothing to restrain the further flow of plastic. In the "short shot" process, or when nearly filling the cavity in a "full shot" process, there may remain unsightly visible hesitation lines or marks on the molding surface at the position of the first plastic injection.

[0011] Another method is disclosed in Japanese Patent Application No. 50-74660, where shut-off valves in runners connect the product cavity and "secondary cavities." In this application, the mold cavity is filled with thermoplastic resin and then a core resin or gas is injected into the cavity while the thermoplastic resin in the mold is expelled from the mold cavity. After the thermoplastic resin fills the mold cavity, the core resin or gas is injected while the resin in the mold cavity is expelled.

Summary of the Invention

[0012] It is an object of the present invention to provide an improved gas assisted molding process for use in the injection molding of plastic materials, particularly hollow tubular products. It is another object of the present invention to provide an improved gas assisted plastic injection molding process which accurately controls the volume of plastic into the mold cavity and secondary cavity.

[0013] It is still another object of the present invention to provide a gas assisted plastic injection molding process in which a good reproducibility of the mold cavity surface on the molded product is produced and flow or weld marks and hesitation marks are minimized or eliminated. It is a still further object of the present invention to provide a gas assisted plastic injection molding process which has improved gas core out with larger expulsion of plastic, thereby reducing the weight and molding cycle time and securing more consistent wall or skin thickness.

[0014] It is still another object of the present invention to provide a gas assisted injection molding process which is suitable for use with a wide range of plastic materials,

including gas-filled nylon and other filled materials and is also suitable for multi-product cavity molds. It is a still further object of the present invention to provide a process for forming hollow tubing components, particularly those which are dimensionally stable.

[0015] The present invention provides a gas-assisted plastic injection molding process which meets the above objectives and provides an improved process for molding plastic products. In accordance with the present invention, molten plastic material is first injected into the mold cavity. One or more secondary cavities are positioned adjacent the mold cavity and each is provided with a certain volume. It is generally necessary to adjust the volume of the cavities after the first or subsequent mold test trial in order to match the volume of each secondary cavity with the volume of plastic required to be expelled from the molding cavity. This may be done by metal removal from the mold to increase the volume, or addition of metal to reduce the volume. Shutoff valves are positioned between the mold cavity and secondary cavities. The plastic material in the mold cavity is pressurized by the molding machine immediately after filling. The "packing pressure" from the molding machine is maintained for a predetermined time period.

[0016] Thereafter, gas is injected into the molten plastic to continue pressuring the plastic material in the mold cavity. Again, after a predetermined time period to allow pressurization of the gas to press the plastic material against the surfaces of the mold cavity, the valves positioned between the mold cavity and the secondary cavities are opened enabling the expulsion of a volume of plastic sufficient to fill the mold cavity or cavities. Initially, the volume of plastic expelled is determined by the time at which the valves are opened. If the valve opening time is prolonged, more of the plastic solidifies in the mold cavity, i.e. the solid skin of the plastic will thicken, and less is expelled; conversely if the valve opening time is advanced, i.e. the delay in opening is reduced, the skin thickness is reduced and more plastic is expelled. When the balance of secondary cavity volume and valve opening time is optimized, the process can be operated consistently shot-after-shot in production. This precisely controls the volume of expelled plastic material. The gas pressure is again held in the mold cavity until the plastic material cools and solidifies. Thereafter, the gas is vented or exhausted from the mold cavity, the mold is opened, and the part is removed or ejected.

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[0017] The volume of plastic material which is expelled from the mold cavity into the secondary cavity is not dependent on the timing of the gas injection. Instead, the volume of plastic expelled is dependent on the volume of the secondary cavity or cavities.

[0018] In an alternate embodiment, at least two secondary cavities are provided. Each are connected to the mold cavity with a separate valve. Each of the secondary cavities is connected to the article mold cavity by a flow runner or conduit in which there is a valve member. The operation of each of the valves is independently controlled and timed. The opening of the valves can be sequentially timed to optimize the required expulsion of plastic from the mold cavity and from different positions in the mold cavity.

[0019] In another embodiment of the invention, the plastic expelled by the gas is forced or drawn back into the injection machine barrel either separately or in combination with one or more secondary cavities.

[0020] In a still further embodiment, the opening and closing of the valve members may be operated to allow the flow of plastic from the mold cavity to the secondary or overflow cavities by the application of a selected pressure exerted by the injection of gas. The injection of the gas would transmit pressure to the plastic material, which in turn will open the valve members and overcome a preset closing force. A preset closing force may be applied to the valve member by mechanical springs, pneumatic mechanisms, hydraulic mechanisms, electrical mechanisms, or the like.

[0021] The opening of the valve members may be controlled in any conventional manner, such as mechanical, pneumatic, hydraulic, electric, or other means. The control can be either digital or computer timed and can be external or integral with the gas pressure control means.

[0022] In order to form high quality hollow tubular components, the flow of plastic and gas are controlled in the axial direction. The gas flows essentially along the tubular section and expels plastic material uniformly throughout the length of the tube. The plastic can be injected from a thinner section at the apex of a cone configuration which allows the plastic flow to expand gradually up to the maximum required cylindrical section. The plastic itself is preferably fed through a peripheral film gate from a runner surrounding the gate section feeding into the apex of the cone. Also, the speed of the

plastic injection is controlled from an initially slow rate and increasing to a faster rate after the cone is filled and as the plastic completes the filling of the cylindrical section. Once the control of the gas injection speed and the pressure is achieved, the valve is opened to the secondary cavity allowing the plastic in the center of the tubular component to be expelled. With this embodiment, it is also preferable for the distal end of the tubular section to have a cone-shaped configuration which gradually reduces the flow of plastic to a thinner section. This allows the expulsion of the plastic to be controlled through the outflow runner and stop valve.

[0023] Other objects, features, and benefits of the present invention will become apparent from the following specification when viewed together with the accompanying drawings and appended claims.

Brief Description of the Drawings

[0024] FIGURES 1A-1E illustrate a sequence of steps in a preferred embodiment of the present invention;

[0025] FIGURE 2 is a graph further illustrating the in mold pressure time sequence embodiment of the present invention as set forth in Figures 1A-1E;

[0026] FIGURES 3A-3E illustrate an alternate embodiment of the present invention;

[0027] FIGURES 4A-4F illustrate an alternate embodiment of the invention in which two secondary cavities are utilized;

[0028] FIGURES 5A-5E illustrate a sequence of steps in another preferred embodiment of the present invention, particularly used for the manufacture of hollow tubular components; and

[0029] FIGURES 6 and 7 illustrate alternate embodiments at the entrance end of the hollow tubular component embodiment.

Description of the Preferred Embodiment(s)

[0030] Figures 1A-1E illustrate the sequence of steps forming a preferred embodiment of the present invention. This process is referred to generally by the reference numeral 10 in the drawings. In Figure 1A, a quantity of molten plastic material

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20 is positioned in the barrel 22 of an injection molding machine (not shown). The injection molding machine can be of any conventional type and can expel the plastic material from the nozzle 24 of the barrel in any conventional manner, such as by a helical screw or a piston 26. Although a piston member 26 is shown and illustrated and described in Figures 1A-1E, it is to be understood that any conventional mechanism used to expel the plastic material from a barrel of an injection molding machine can be utilized.

[0031] As shown in Figure 1A, the nozzle 24 of the injection molding machine is connected to a mold cavity 30. The mold cavity 30 is positioned in a conventional mold which in turn is positioned in a conventional molding machine (not shown). A secondary cavity 32 is positioned in communication with the mold cavity 30. A valve member 40 is positioned between the nozzle 24 and the mold cavity 30 while a second valve member 42 is positioned in the conduit or runner 44 positioned between the mold cavity 30 with the secondary cavity 32. The valve members 40 and 42 can be of any conventional type, such as shut-off type valve members, and can be operated in any conventional manner, such as pneumatically, hydraulically, electrically, etc. Control of the valve members 40 and 42 can also be accomplished with any conventional mechanism or system. For example, the mechanism can be computer operated so that the valves can be accurately timed to open and close as desired in accordance with a prespecified injection molding process.

[0032] The quantity of plastic material 20 in the barrel 22 of the injection molding machine is sufficient to fill or substantially fill the volume of the mold cavity 30. The plastic material 20 which can be used or utilized with the present invention can be of any conventional type, such as a thermoplastic resin. The plastic material can also be a filled material, that is mixed with a glass or mineral material.

[0033] In an alternate embodiment, one or more secondary cavities can be provided. The secondary cavities are each connected to the mold cavity 30 by separate runners. Also, independently controlled separate valve members are positioned in each of the runners or conduits between the mold cavity 30 and the secondary cavities. In this embodiment, the overflow cavities can be filled separately and timed in order to allow the plastic material to be expelled as desired and where necessary in order to optimize the production process and plastic product produced by the process.

[0034] Referring back to Figure 1, the second step in the process is shown in Figure 1B. In this step, the plastic resin material 20 is injected by the injection molding machine into the mold cavity 30. The plastic material in the mold cavity is then pressurized by the molding machine ("packing pressure") for a short period of time, for example 1-5 seconds. This insures good reproducibility of the mold surface on the molded article in the cavity. For this process step, valve member 40 is opened in order to allow plastic material to enter the mold cavity 30, but valve member 42 is retained in a closed position in order to prevent any plastic from entering the secondary cavity 32.

[0035] At this point, the gas is injected at selected ram and hold pressures. In the schematic embodiment shown, gas is injected through inlet conduit 50. Initially, the valve member 42 remains in a closed condition for a predetermined amount of time such that the pressure of the gas in the molten material 20 forces the plastic material against the inner surfaces of the mold cavity, again helping to provide a good surface finish on the plastic product. This is shown in Figure 1C.

[0036] Thereafter, as shown in Figure 1D, the valve member 40 is closed and the valve member 42 opened. The pressure of the gas 52 in the molten plastic material 20 in the mold cavity 30 causes molten plastic to be expelled from the mold cavity into the secondary cavity 32. In this regard, the molten plastic material is preferably expelled from the center of the thicker sections in the molded article through the connecting gates or runner 44. Thereafter, a gas "hold" or "packing" pressure is maintained in the mold cavity while the plastic material cools and solidifies. This takes on the order of 10-25 seconds or longer, depending on the size and thickness of the molded plastic product.

[0037] It is generally necessary to adjust the volume of the cavities after the first or subsequent mold test trial in order to match the volume of each secondary cavity with the volume of plastic required to be expelled from the molding cavity. This may be done by metal removal from the mold to increase the volume, or addition of metal to reduce the volume. Initially, the volume of plastic expelled is determined by the time at which the valves are opened. If the valve opening time is prolonged, more of the plastic solidifies in the mold cavity, i.e. the solid skin of plastic will thicken, and less is expelled; conversely, if the valve opening time is advanced, i.e. the delay in opening is reduced, the skin thickness is reduced and more plastic is expelled. When the balance of secondary cavity

volume and valve opening time is optimized, the process can be operated consistently shot-after-shot in production.

[0038] The amount of plastic material which is expelled into the overflow cavity can also be controlled by the time at which the valve member 42 is opened.

[0039] It is also possible to operate the present process without use of a valve such as valve 40 positioned between the injection molding machine and the mold. It is preferable to include a valve such as 40, however, in order to prevent plastic from being forced back into the screw cylinder when pressurized by the gas.

[0040] Once the plastic product has sufficiently cooled and solidified, the gas 52 is exhausted, for example, back through conduit 50. This is shown in Figure 1E. The expelled gas can be either collected and reclaimed for further use, or expelled into the atmosphere. Mechanisms and systems for exhausting or venting pressurized gas from the interior of the molded article preparatory to opening the mold are described in numerous patents in the prior art. In this regard, any conventional mechanism or system for exhausting or venting the gas from the mold and molded article can be utilized in accordance with the present invention. At the same time that the gas is exhausted, the piston or ram 26 of the injection molding machine is typically retracted to its rest position to enable ejection of the molded part and in preparation for another shot of plastic material.

[0041] Once the gas is vented or exhausted from the mold cavity, the mold is opened and the finished plastic product is ejected or removed from the mold cavity. At the same time, the expelled plastic material 21 in the secondary cavity 32 is similarly ejected or removed from the mold. The plastic in the cavity 32 can be reground and reused, if desired, or the cavity itself can be used to form another plastic part for possible use.

[0042] In some cases, the use of a nozzle shut-off valve 40 or hot runner valve gate is recommended to prevent reverse flow of plastic back into the barrel of the injection molded machine. Also, it is preferred to reground the runner and plastic material in the secondary cavities to avoid waste of material. Further, if it is necessary to adjust the volume of the secondary cavity after initial molding trials, this can be done by removing

or machining metal in order to enlarge the secondary cavity or by adding metal to reduce the size of the cavity.

[0043] The positioning of the gas injectors in the mold cavity should preferably be adjacent to the thicker sections and remote from, and at the opposite extremity to, the expulsion gates and runners. Also, the positioning of the plastic feed gates in the mold cavity should be selected to optimize the flow of plastic into the mold cavity. It may be necessary to prevent in-mold gas pressure from forcing the plastic back into the machine with a shut-off valve, by holding the ram screw forward, or by use of a hot runner system with valve gates.

[0044] A graph illustrating the sequence of steps described above is shown in Figure 2. The graph is referred to generally by the reference numeral 60 in Figure 2 and charts the molding cycle time relative to the plastic pressure in the mold. In this regard, the pressure in the mold initially increases as shown by line 62 as the plastic is injected into the mold cavity. The molding machine then holds the plastic packed pressure as shown by line 64. The time at which the machine packs the pressure is indicated by the arrow 66. That time can be adjusted as desired.

[0045] Thereafter, as shown by line 68, the gas is injected into the plastic material in the mold cavity. At point 70, the valve member 44 regulating the flow of plastic material into the secondary cavity is opened. This allows plastic to be expelled from the mold cavity into the secondary cavity. This step is indicated by the arrow 72. Thereafter, the pressure of the gas in the mold cavity is held. This is shown by line 74. The time of the gas packing pressure is shown by the arrow 76 in Figure 2.

[0046] Subsequently, the gas pressure is reduced in the mold. This is shown by line 78. The gas pressure can also be held constant for a period of time, as shown at 80, in order to allow the plastic material to cool and harden. Thereafter, that is once the plastic part is cooled and hardened, it is ejected from the mold. Once the pressure of the gas is vented or exhausted from the mold cavity, as shown by line 82, the mold is opened and the part removed. This is shown at point 84 on the graph of Figure 2.

[0047] With the system and process of the present invention, the method is not dependent on the injection of an accurately controlled shot volume of plastic repeatedly

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shot after shot. Also, the ability to pressure pack the plastic while the article cavity is filled with plastic, or is filled with plastic and initial injection of gas, insures accurate replication of the mold cavity surface without shrinkage of the plastic from the surface.

[0048] Avoiding the need to partially fill the article cavity eliminates the tendency to form hesitation marks on the product at positions to which the plastic flows and stops before the gas is injected.

[0049] The dependence on a fixed volume of plastic material which is expelled from the mold cavity eliminates the variable dependence on timing of the gas injection. Also, the present invention is suitable for multi-cavity molds, with each cavity being able to be connected to one or more secondary cavities. It is not believed practical to depend on the balancing of the flow of plastic in order to partially fill each cavity.

[0050] The present invention is suitable for a wide range of thermoplastic resin materials, including glass-filled fiber materials which require early pressurization in order to achieve acceptable surface finishes. Also, a more consistent and uniform wall section thickness is achievable throughout the molding channel as a result of more positive control of the gas and plastic flows. The process is further operable on molding machines which are not capable of accurately delivering consistent volumes of plastic material.

[0051] The position of the gas injectors in the mold cavity is not as critical as it is with other processes in which overflow cavities are utilized. In this regard, the present invention is suitable for expelling plastic from more than one position in an article cavity. Also, the valve members into the secondary cavities can be sequentially opened and closed in order to optimize plastic expulsion and to avoid thick accumulations of plastic remaining in the molded article.

[0052] An embodiment of the invention in which more than one secondary cavities are utilized is shown in Figures 4A-4F and designated generally by the reference numeral 150. The embodiment 150 includes an injection molding machine 152 which is set up to inject a quantity of molten plastic material 154 into a mold cavity 156 in a mold. The primary mold cavity 156 has a pair of secondary cavities 158 and 160 which are connected to the mold cavity 156 by conduits or runners 162 and 164, respectively. Valve members 166 and 168 are positioned on the conduits and act to open and close the flow of plastic

from the mold cavity 156 to the secondary cavities. Another valve member 170 is positioned at the inlet to the primary mold cavity 156 (or in the nozzle) and used to open and close the conduit 172 which connects the inject molding machine nozzle to the mold cavity. Port or pin member 174 is used to inject gas into the mold cavity.

[0053] The sequence of steps for use of system 150 is illustrated in Figures 4A to 4F. Plastic material 154A is first injected into the mold and retained there for a brief period of "packing pressure" (Figure 4B). Gas 180 is then injected into the plastic material in the mold and the pressure is held for another period of time (Figure 4C). Valve member 166 is then opened and a first quantity of plastic material 154B is expelled into a first secondary cavity 158 (Figure 4D). Thereafter, valve member 168 is opened and a second quantity of plastic material 154C is expelled into a second secondary cavity 160 (Figure 4E). Once the part has cooled and solidified sufficiently, the gas is exhausted back through port 174 (Figure 4F). In the final steps, the mold is opened, the part is ejected, and the system is prepared for the start of another cycle.

[0054] The embodiment shown in Figures 4A-4F is representative of any system in accordance with the present invention in which more than one secondary cavity is utilized. Variations and changes can be made by persons of ordinary skill in the art to develop other multiple secondary cavity systems. It is often advantageous to expel plastic material into second, third, or even fourth secondary cavities in order to relieve thick sections of the plastic remaining after the first expulsion. This can be evident in a non-uniformly thick section molding such as an automobile door handle.

[0055] With the present invention, the injection of an unpressurized accurate shot weight or filling volume is not necessary. Also, the timing of the gas injection is not as critical. The packed pressure exerted by the molding machine and subsequently the gas when the cavity is full of plastic material insures a good reproducibility of the mold cavity and the molded article itself. Flow or weld marks are reduced. Also, the appearance of hesitation marks, when partial filling of a cavity is desired, ceases to be a concern with the present invention.

[0056] The operation of the valve member 42, as well as any other valve members which are positioned between the mold cavity and the secondary cavities, can be operated independently and timed to be sequential with the other secondary cavities. This allows

the plastic to be expelled from the mold cavity in a desired sequence and in order to allow formation of various channels in various thicker sections or members of the product. Also, as noted, the volume of plastic expelled from the mold cavity is not dependent on the timing of the gas. Instead, it is dependent on the timing of the valves and the volume of the secondary cavity or cavities and the opening and closing sequence of the valve members from the mold cavity into the secondary cavities.

[0057] In a further embodiment of the present invention, the valves in the runners or conduits between the mold cavities and the secondary cavity or cavities can be operated in a different manner. The valve members may be operable by the application of a selected pressure which is exerted by the injection of gas and in turn a transmission of pressure to the plastic material. This in turn will open the valve member, thus overcoming a preset closing force. The preset closing forces may be applied to the valve members by mechanical spring members or other means, such as pneumatic, hydraulic, or electric.

[0058] Further, the opening and closing of the valve members may be controlled by any conventional means, such as pneumatic, hydraulic, electrical, or mechanical means. The opening and closing of the valve members can also be controlled by external means which may include digital or computer timing, external or integral with the gas pressure control means.

[0059] As an alternative to expelling the plastic material into secondary cavities, it is also possible to expel the plastic material back into the injection molding machine barrel. This is accomplished by the gas pressure pushing back the injection screw or piston against a controllable back pressure. This process is shown in Figures 3A-3E and referred to generally by the reference numeral 100. As shown in Figure 3A, plastic material 102 is positioned in a barrel 104 of an injection molding machine (not shown). The barrel 104 has a nozzle 106 which is connected in any conventional manner with a mold cavity 108. A valve member 110 controls the flow of plastic from the barrel member into the mold cavity. At the initial sequence of steps, as shown in Figure 3B, the valve member 110 is opened allowing plastic material to be expelled or injected from the barrel 104 into the mold cavity 108. Thereafter, the pressure is temporarily held by the injection molding machine relative to the plastic in the mold cavity 108, preferably for at least 1-5 seconds.

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[0060] Thereafter, as shown in Figure 3C, gas is injected into the plastic material in the mold cavity through gas injection conduit 120. The gas 122 expels the plastic back into the machine cylinder and forms a hollow cavity in the plastic material in the mold cavity 108.

[0061] At this point, the pressure is reduced from the molding machine screw or plunger member 130 which enables expulsion of molten plastic material 102 from the mold cavity back into the machine cylinder or barrel 104. Space in the barrel 104 can be formed by the force of the gas forcing the plunger member 130 away from the mold.

[0062] Following completion of plastic expulsion, the gas pressure is held during cooling and solidification of the plastic material in the mold cavity. This is shown in Figure 3D. At this point, the plastic is subjected to packing pressure and has its surface forced tightly against the inside surfaces of the mold cavity. This produces a good surface finish and creates a full definition of the surface of the mold. Thereafter, the gas pressure in the mold cavity is reduced under control to atmospheric pressure. This is shown in Figure 3E. Thereafter, the machine barrel 104 is completely refilled with plastic material and ready for the next molding cycle. At the same time, the mold is opened and the formed plastic part is removed or ejected from the molding machine.

[0063] The advantages of this alternate embodiment of the present invention is that the expelled plastic can be remolded in succeeding shots. This eliminates regrinding or recovery of the expelled material from a spillover or secondary cavity. Also, retrimming of the molding is not necessary, and the system does not have to expend the cost of additional shutoff valves in the runner members.

[0064] The present invention also can be used in the manufacture of hollow tubular components. A preferred molding system and process for this is shown in Figures 5A-5F, while other embodiments of portions of this mechanism and system are illustrated in Figures 6 and 7. There is a need today for the manufacture of hollow tubular components from plastic materials. These components can be used, for example, as rollers for printers. The tubular components have to be dimensionally stable and straight circular cross-sections with concentric hollow intersections in many cases. It is also desirable to include features in the molding which could normally not be extruded, but which are possible with injection molded products. These include grooving or screw threads on the

outer surface, brackets and other external fittings, connection mechanisms for use as spindles, and the inclusion of gear teeth or polywheel configurations to provide ways to rotate the roller.

[0065] With conventional injection molding techniques, either as a solid section or with mechanically moving side cores to form the inter-tubular section, it is difficult to achieve flatness without distortion over the length of the component and to reduce molding time cycles. In prior attempts to use gas assisted molding for hollow products or components, it has proved difficult to achieve concentricity and uniform wall section thickness along the length of the tubular components.

[0066] In order to achieve axial flatness over the length of the tubular section, uniform shrinkage of the plastic as it cools and changes from a liquid into a solid should be achieved. It is also important to eliminate or minimize stress in the molding of the plastic since molding stresses can cause ejected parts to distort or warp. Injection molded plastic parts which have stress in them have a tendency to relieve that stress by distortion and warpage of the component after they are ejected from the mold.

[0067] With the present invention, concentricity and uniformity of wall section can be achieved. The plastic and gas flows are controlled in an axial direction, and there is no random or uncontrolled sideway movement or turbulence in the plastic flow. The gas flows axially at the center of the tubular section and is utilized to expel the plastic uniformly throughout the length of the tube into the secondary cavity or cavities. There is no lateral movement of the plastic after forming and within the semi-molten skin adjacent to the mold cavity surface. A uniform rate of cooling is achieved since there is good temperature control of the mold cavity members and there is a good plastic to mold surface contact to insure uniform conduction of heat from the plastic.

[0068] In order to achieve a flow of plastic without turbulence, a mold cavity is formed which has a circular middle section and two cone-shaped configurations at the two ends. The plastic is injected through a peripheral film gate from a runner surrounding the gate section feeding into the apex of the cone at the inlet end. The plastic is injected along a thinner section and it flows and expands gradually along a cone or cone-like configuration up to the maximum required cylindrical section.

[0069] The gas is injected in a central position along the axis of the tube and used to expel the plastic from the center. The gas is injected near the apex of the cone in order to allow a gradual expansion into the desired intersection of the plastic. The speed of plastic injection is controlled from an initially slow rate and increased to a faster rate after the cone is filled and as the plastic completes the filling of the cylindrical section. The speed of the plastic injection slows again before the final cavity filling is completed.

[0070] The control of the gas injection speed, and therefore the pressure, is also controlled such that the gas is injected at a low pressure before expulsion of the plastic begins. This means that the pressure in which the gas is injected is lower before the opening of the valve in the runner or conduit which connects the product cavity to the secondary cavity.

[0071] The tubular section at the distal end of the product cavity adjacent to the secondary cavity can be reduced in size to gradually reduce the flow of plastic to a thinner section. This allows the expulsion of the plastic to be controlled through the outflow runner and stop valve into the secondary cavity. In this regard, a second cone-shaped cavity configuration is shown in the drawings and described below, but it is to be understood that any shape or configuration can be utilized at the distal end of the mold cavity. Also, although it is preferred that the cross-sectional size be reduced at the distal end of the cavity, this is not a requirement of the invention.

[0072] A preferred sequence of steps which can be utilized in the plastic expulsion process in order to manufacture hollow tubular components is shown in Figures 5A-5F. The process is generally referred to by the reference numeral 200 in the drawings.

[0073] As shown in Figure 5A, the mold cavity 202 generally has a central elongated portion or section 204, a cone shaped configuration 206 at the leading end (that is the entrance at which the gas and plastic are injected into the cavity), and preferably a corresponding cone-shaped configuration 208 at the distal end adjacent the secondary cavity 210. A valve member 212 is positioned in the conduit or runner connecting the mold cavity 202 with the secondary cavity 210. The valve member can be any conventional type, such as those described above with reference to Figures 1-4.

[0074] Plastic is introduced into the mold cavity 202 through runner 220 and film gate 222. The plastic feed runner 220 and the plastic gate 222 are better shown in figures 6 and 7.

[0075] The gas is injected into the mold cavity from gas injector port 230 which is positioned at the apex of the cone-shaped inlet section 206. Gas is directed to the port 230 from conduit or inlet line 232.

[0076] Also, as shown in Figures 6 and 7, it is possible to have a moving core 240 as part of the mechanism and system.

[0077] As shown in Figure 5B, the sequence of the molding process includes the initial injection of plastic material into the mold cavity 202. At this point, the valve member 212 is closed. After the plastic is injected into the mold cavity, the plastic is pressurized or packed in the cavity in order to provide good surface characteristics of the outer surface of the molded component. In this regard, the plastic is pressurized and compacted for a short dwell period of time, on the order of 1-5 seconds, by the molding machine. This insures good reproducibility of the mold surface on the molded product or article and good replication of the mold cavity shape.

[0078] Thereafter, as shown in Figure 5C, the injection of the gas is commenced. The gas which is shown schematically by the reference numeral 250, continues to apply pressure within the plastic in the mold cavity 202. After a short dwell time in which the plastic pressure is utilized to assist in forcing the plastic against the internal walls or surfaces of the mold cavity, the valve member 212 is opened. This is shown in Figure 4D.

[0079] With the valve member 212 opened, the molten plastic material in the center of the mold cavity 202 is allowed to be expelled from the mold cavity. The expulsion of the molten plastic is taken from the center of the tubular section and enters the secondary cavity 210 through the connecting runner 214. In Figure 5D, the hollow center of the tubular component, which is filled with gas, is indicated by the reference numeral 250, while the outer plastic now tubular component is referred to by the reference numeral 252. The plastic material in the overflow cavity 210 is referred to by the reference numeral 252A.

[0080] When the expulsion of plastic is complete, the gas pressure within the inner tubular channel is maintained so that the outer surface of the plastic remains in contact uniformly with the mold cavity surface, thereby insuring uniform conduction of heat from the plastic to the mold.

[0081] After complete solidification of the plastic tubular component, the gas pressure is relieved and the gas is exhausted from the mold. This is shown in Figure 5E. Thereafter the moveable core (if utilized) is removed from the mold cavity and the mold is opened and the part ejected. The portion of the plastic material 252A in the secondary cavity 210 is also ejected at the same time. In this regard, as indicated above, the plastic material in the secondary cavity can be reground and used again, can be scrapped, or can be made into another plastic component or part having the shape of the secondary cavity.

[0082] Once the plastic tubular component is formed and ejected from the mold, post molding operations are necessary in order to trim off the cone sections at each end. This forms the final hollow tube or component.

[0083] The cone-shaped sections or configurations 206 and 208 of the mold cavity 202 preferably have included angles up to between 10-60 degrees. This assists in the uniform axial fill of the plastic from the apex of the cone and allows the plastic to expand up to the maximum cylindrical section as required in order to avoid turbulence or non-uniform flow of the plastic.

[0084] Injecting the gas at an axial direction from a gas injection assembly or port 230 mounted in a moveable core assembly 240 enables the gas injector to be withdrawn axially from the molded component before the mold is opened and the part is ejected.

[0085] As an additional embodiment, the moveable gas injector and plastic feed gate can be combined in order to feed the plastic to a ring gate configuration in which the plastic flows from a ringed runner formed around the gas injector barrel, and then through a thinner ringed gate flowing into the mold cavity so that it is coaxial with the gas injection when the gas is injected after the mold filling is complete. This is illustrated preferably in Figure 7. An alternate configuration of the plastic runner can be utilized where the runner is formed by a groove between the enlarged moveable core and the mold plate. This is illustrated in Figure 6.

[0086] It is possible in accordance with the hollow tubular embodiment of the present invention to use the alternate version of the plastic expulsion process as described above with respect to Figure 3 A-E. In this alternative embodiment, the molten plastic is expelled back into the molding machine cylinder, rather than into a secondary cavity. The expelled plastic forces back the screw in the barrel of the molding machine to provide the necessary controlled space volume within the cylinder.

[0087] For this alternate embodiment, the gas is injected from a cone extension of the tubular component at the opposite end to the plastic feed gate section. The gas injector is mounted on a moveable side core which injects the gas into the mold cavity in an axial direction, thereby expelling a uniform flow of plastic exiting from the cone-shaped feed section, through the feed gates, runners, and sprue and back into the machine cylinder. With this alternate embodiment, the pressure is again maintained in the mold cavity in order to force the plastic against the surfaces of the mold cavity. As stated above, this insures good service replication and uniform conduction of heat from the plastic to the mold.

[0088] As stated above, the present invention enables the manufacturer of an injection molded tubular structure of component. The component is molded as one piece and can be molded together with additional features, such as pulley wheels, gear wheels with profiled teeth, or with screw threads, grooves, or other profiles on the outer surface of the tubular section. These additional features can be formed by machining applicable cavities for them in the mold cavity surfaces.

[0089] While particular embodiments of the invention have been shown and described, numerous variations and alternative embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.